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The Ventilation of the SCHOOL ROOM

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FRESH AIR.

THE VENTILATION

OF THE

SCHOOL ROOM,

—BY—

WM. J. BALDWIN, M. AM. SOC. C. E.,

MEM. AM. SOC. MECHS. ENGS.

EXPERT

AND

CONSULTING ENGINEER.

HEATING AND VENTILATION.

(*Copyrighted, 1901.*)

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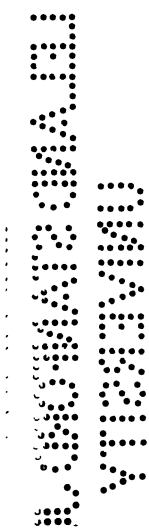
TO

ABRAHAM ABRAHAM, Esq.

OF BROOKLYN,

IN CONSIDERATION OF THE INTEREST HE TAKES

IN THE SUBJECT.



IN 1897 the author published a little *blue* book, called "Data for Heating and Ventilation," and in its preface he promised to continue his efforts in a similar line at a later date, provided the endeavor he then made was appreciated.

The demand and the appreciation for the "blue" book was greater than his anticipations, and the many letters asking to be remembered when another book was issued, induced him to produce a *red* book for the year 1899, and call it "An Outline of Ventilation and Warming."

He now issues his little "white" book under the title of *The Ventilation of the School Room* (1901) and he trusts that in the future he may be able to continue his work in similar lines.

The author has the honor to be the *pioneer* American writer of a book of reference on steam heating, etc. This book known as "Baldwin on Heating" from the press of John Wiley & Sons, has now reached its 15th edition; something that no other engineering work ever printed in America has attained.

83858

THE VENTILATION OF THE SCHOOL ROOM.

Perfect Ventilation?

I PRESUME the word "perfect" should never be associated with the word "ventilation."

What is "perfect ventilation?"

If one lived in a tube, taking air at the bottom and discharging it at the top, and the air was taken from the top of one of the highest mountains, presumably it would satisfy the person who is looking for "perfect ventilation."

Under the ordinary conditions of our lives, in our homes, at our business, in school, in the theatre, we have to take what we can get in the matter of ventilation, or more properly speaking, *air*, fresh or foul *and make the most of it* for the time being; and the only way we can help ourselves, is by simply avoiding the places, when it is possible, where we know the ventilation to be either very bad or none at all, and patronize the places in

which there is some systematic attempt at ventilation.

We cannot live in tubes, and we therefore live in houses, in fellowship with our kind, breathing the same air with them and helping to contaminate it, and an analysis of the air taken at the outlet will be a fair sample of what we breathe, each person having added his or her quota of contamination ; the same mingling with the mass : although at the same time, through some properly arranged inlet and outlet, there may be passing a stream of air, the inlet presumably fresh, and the outlet more or less contaminated.

This is all we can hope for while we live together, and our effort should be to secure "good" or "fair" results under the normal conditions of human life, and not look for an ideal condition that is impossible to attain. This is why the word perfect should be omitted in a ventilating specification, as no one can attain it.

I may now ask "what is ventilation?" (in contra distinction to "perfect ventilation" as quoted above.) This question may be answered

by saying, that any means whereby the air of habitations can be maintained at some common standard of purity, can be termed "ventilation."

The "standard" can be placed higher or lower as the local conditions may seem to require, or the persons interested can afford.

Movements of confined air, which simply produce a sense of cooling, must not be confounded with *true* ventilation.

A room or building may be well ventilated from a hygienic standpoint, and still be deemed uncomfortable to live in by being over or under-heated. If it is over-heated, the unthinking person is apt to say the ventilation is bad, while as a matter of fact, it may be that only the warming is improperly done; and this is why the question of warming and ventilating have to be considered together in all cold climates.

I am not, however, going to consider the question of warming here, any farther than is necessary to properly present the question of fairly good or good air in habitations, schools or other inclosed space.

I have made tests in a hospital as to the quantity of air that was moving through it, and found that the average amount of air per bed was between 7,000 and 8,000 cubic feet per hour. At the same time, the physician in charge declared that the ventilation of the hospital was "abominable." His opinion was not based on the chemical analysis of the air. It was based on the fact that the room was too warm. A room receiving but 1,000 cubic feet of air per bed might pass as "fairly well" ventilated provided the temperature was comfortable.

I only cite the case of the physician to show how educated persons may err on the subject of ventilation, when the personal feelings alone are the instruments with which one measures the standard of purity.

"What is the standard of purity at which air should be maintained?" The necessity for a standard of purity implies, of course, that individuals contaminate the air of habitations, and that sufficient fresh air must be admitted and an equal amount expelled or withdrawn until the air within

the building is kept at a degree of purity very nearly equal to the purity of the outside air. This is ventilation, but it has not answered the question of a *working standard of purity.*

The writer knows of many buildings that are even as yet being used as schools or places of education, that are almost, if not entirely, without ventilation in the proper sense of the term.

The principal of a ladies' seminary in Greater New York, while showing the mother of a prospective pupil her institution, explained the advantages of having large dormitories divided into small rooms, with partitions that did not run to the ceiling, by saying, "We get the most perfect ventilation thereby—a free movement of the air from one room to the other;" and when it was suggested that the air of one room was probably no better than the air of the other room, she explained, that "As soon as the pupils retired, they covered their heads with the bed clothing, and that all the windows were opened for about ten minutes, thus removing *every particle of contamination.*" That was *her* standard.

Twenty years ago, fifteen years ago, and probably not more than ten years ago, the Public Schools of New York were almost without ventilation. At the present time, however, whatever may be said against the school system of New York, it cannot be said that they are not making a most determined effort to secure a good standard of purity in the air of the rooms. We may differ with them in their methods, and be disappointed in the results sometimes obtained, but nevertheless, the present management deserve the highest commendation for their efforts.

PETTENKOFER'S EXPERIMENTS.

Pettenkofer has demonstrated by careful scientific cabinet experiments on an individual, 28 years of age, whose weight was 132 pounds, the amount of carbonic acid that the person would add to the atmosphere in which he lived and breathed in a given time.

He found that "in repose" the individual added .00424 cubic feet of carbonic acid per hour (reduced to the volume of 32 degrees Fahrenheit) *per pound*

weight of his body; and that under what he considered "gentle exercise," he added .0059 cubic feet (per hour per pound weight of his body); and that the amount reached .01227 for "hard work:" all of which reduced to correspond to a person weighing 142 pounds (assumed average weight of adult human beings) would amount to .6 cubic feet of carbonic acid for a person "in repose;" .9 for a person at "gentle exercise;" and 1.8 per hour when doing "hard work."

A STANDARD OF PURITY.

With the foregoing in view, what should the standard of purity be? and the amount of air admitted per person to maintain it?

Able authorities are of the opinion that when the CO_2 is maintained at .0002 in excess of what is found in the outer air, that it is at least good; in which case there will have to be admitted 3,000 cubic feet of fresh air per person per hour while "in repose" 4,500 cubic feet for persons at "gentle exercise;" and 9,000 cubic feet for persons at "very hard" or laborious work.

This certainly seems to be a liberal standard to maintain, and the best authorities now seem to think it is ample in cold climates in winter, as the cost of ventilation must enter into the question, particularly when a great number of persons have to be provided for in comparatively restricted space, such as hospitals, schools, etc.

It is customary in hospitals to provide for a minimum admission of 3,000 cubic feet of air per bed per hour, with mechanical means of increasing the admission to 6,000 cubic feet of air per bed per hour, when it is deemed necessary. This amount of air (3,000 to 6,000 cubic feet per bed per hour) seems to cover the contingencies and insure a standard, in which the excess or coincident CO_2 will be about .0002. Of course, when half this quantity of air is admitted, other things being the same, the increase of coincident CO_2 will be doubled, and will become about 4 parts in 10,000.

MASSACHUSETTS' LAW.

Under what is known as the "Massachusetts Law," which provides for the admission of 1,800 cubic feet of air per hour per child in the

schools (without regard to weight,) the additional vitiation (carbonic acid) will be about .0003 CO_2 when the average weight is about 90 pounds, which, of course, secures what may be termed a *good* standard of purity, without an excessive cost of maintenance.

PURE CARBONIC ACID NOT A VITIATION.

This treatise does not intend to convey the idea that a certain percentage of the carbonic acid (CO_2) in the air, in its pure state, is a vitiation, as from .0002 to .0004 of CO_2 is nearly always present in what is considered pure outside air, at least in the neighborhood of cities. It does imply, however, that *coincident* CO_2, or the carbonic acid added by the lungs within doors, is the *measure* of the vitiation, as in proportion to it all the other emanations from the animal system, such as aqueous vapor, etc., must and do exist, and that by measuring the excess of carbonic acid, which is easily done, a comparative conception at least of the other contaminations can be formed.

TEST FOR CARBONIC ACID.

Careful tests for carbonic acid in the air should be made by a chemist or one who has made a study of the subject. A crude comparative test, however, can be made by a layman in the following manner:—

Procure a jar of lime water, made by placing a small quantity of ordinary burned lime in a vessel of water. After it has slaked and stood for a time the excess of lime will settle, leaving a clear and pure lime water on the top. Decant the clear water and it is ready for use.

Procure a large necked bottle and make two holes in the cork. In one hole place a tube running near to the bottom of the bottle, the other hole being open. Attach a small bellows to the open end of the tube. Go into the open air and force air into the bottle with the bellows until the water becomes turbid: counting the number of strokes of the bellows. Then enter the suspected room with a fresh bottle full of lime water and renew the action of the bellows until the water becomes as turbid as before: counting the strokes of the bellows. Then, if it is found that it takes only half as many

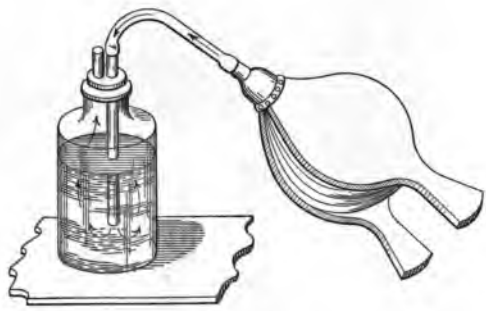


FIG. 1.

strokes of the bellows to produce the same result inside as it did outside, the general conditions may be assumed to be good and the amount of carbonic acid *in excess* can be reasonably supposed to be no greater than the original quantity of carbonic acid outside. If, however, one fourth the number of strokes of the bellows produced the same result, then there would be four times the quantity of carbonic acid inside that there was outside, or three times as much "in excess."

The carbonic acid combines with the lime in the water and makes insoluble carbonate of lime. This, of course, is a crude method, but with practice, fairly accurate estimates can be obtained. The bellows should be opened to its full capacity each time so that the measure will always remain the same.

Figure 1 shows the arrangement I have described, and in the hands of a school teacher will furnish at least an approximation of the amount of vitiation in a class room.

COST OF VENTILATION.

What does ventilation cost? The person who has to provide ventilation for a crowded building in

a cold country, has also to assume the responsibility for the fuel bills, and were it not for this question of fuel, there is no reason whatever why we should limit ourselves in the amount of air passed into or through a building, up to a point of making it draughty.

A pound of coal burned under a boiler is equivalent to warming 486,000 cubic feet of dry air, *one* degree Fahrenheit, when the initial temperature of the air is zero; while at 14 degrees above zero, it will warm 500,000 cubit feet of air one degree: and at 70 degrees above, 562,000 cubit feet of air—in each case one degree Fahrenheit.

This establishes the fact, therefore, that 500,000 cubit feet of air (in round numbers) can be warmed *one* degree Fahrenheit for the *cost* of *one* pound of coal, or 5,000 cubit feet of air can be warmed 100 degrees for the cost of one pound of coal. This is the fuel cost of ventilation. It follows the immutable law of equivalents and cannot be changed materially.

In the neighborhood of New York, it has been found that an average rise of temperature of about

40 degrees Fahrenheit is sufficient to cover the ranges for an ordinary winter; and that an *average* of 50 degrees is sufficiently high for any point within the United States, so that the average amount of air that can be warmed by the burning of a pound of coal in the East, North, West and Middle States of the Union will be between 10,000 and 13,000 cubit feet.

With coal at $5.00 a ton of 2,000 pounds (a fair average for the whole United States) it will require 20c per hour for fuel to maintain the warmth of every *one million* cubit feet of air passed through a building, taking one day with another throughout the winter.

In the case of hospitals, in which the heating is to be maintained day and night, say through 180 days of a year, the fuel for the same time will be $864 for *every million* cubic feet of air passed in an *hour*. This, of course, does not include interest on the plant, labor, service etc., which increases it to about $2,000. *per season per million* cubit feet of fresh air passed into the building *every hour*. As the plant grows larger this can be reduced to

probably $1500. per year for each additional million cubit feet of air admitted per hour. This is the cost of ventilation for hospitals.

This estimate will be considerably modified in the case of schools as of course the schools are not run continuously. The fuel cost per hour, however, will remain about the same (20c for each million cubit feet of air passed through the building). An eight room school will require about 1,000,000 cubic feet per hour—during sessions—for all purposes, increasing at about the ratio of 100,000 cubic feet of air per room as the school building becomes larger.

HORSE-POWER REQUIRED FOR VENTILATION.

When the power or heat required is expressed in horse-power, it is equivalent to about 33.3 centennial horse-power (*continuously*) per million cubic feet of air warmed and passed through the building in an hour.

HOW TO SECURE VENTILATION.

The savage made a hole in the roof of his house to let out the smoke. This was the first attempt

at ventilation and very little improvement was made on this primitive method until about 600 years ago when the fireplace and chimney appeared, and this sufficed for dwellings until about Franklin's time, when he invented the "aspirating stove;" the waste heat of which drew a measure of air out of the room: which air was renewed the best way possible, through window and door cracks and porous building materials.

The early chimney was as a general thing so large that when the doors and windows were closed, the air to supply the fire came down one side of the chimney, while the smoke went up the other side, and this circulation went on even after the fire was out (though in a subdued measure); thus securing "accidental ventilation."

In the latter part of the 17th century systematic ventilation was undertaken by Sir Christopher Wren in the British House of Parliament, London. It was a little better than "some holes in the ceiling."

About 1723 Desaguliers improved the foregoing system by connecting the holes or tubes with heated

chimneys. This is the first well authenticated account of ventilation by "heat aspiration."

About the year 1736 Desaguliers again improved the ventilation of the British House of Parliament by the use of centrifugal fans, which were very similar to the "housed" pressure fan or blower of to-day. This is probably the first well authenticated account of the use of "pressure" and "exhaust" fans to buildings.

It is only within the last forty years, however, that a great and well defined stride has been made in the development of systematic ventilation for habitations. The little that had been done by persons previous to that time was in special cases and only in notable buildings, such as the Capitol at Washington and some hospitals and asylums, and it is probable that General Arthur Morin, Director of the Conservatory of Arts and Trades, Paris, was the first to disseminate and give a clear understanding, in his writings, of the true principles of modern systematic ventilation, and I suggest for the consideration of all students a translation of his work on "Warming and Ventilation in Occu-

pied Buildings," a translation of which by Mr. Clarence B. Young, appeared in the annual reports of the Board of Regents of the Smithsonian Institute for the year 1873 and 1874.

He recommended as the amount of air to be changed every hour to preserve the healthful condition of the room, as follows :—

	Cubic Feet.
Hospitals:	
For ordinary cases of sickness	2,119—2,472
For surgical and lying-in cases	3,532
During epidemics	3,709
Prisons	1,766
Workshops:	
Ordinary occupations	2,119
Unhealthful occupations	3,532
Barracks:	
During the day	1,059
At night	1,413—1,766
Theatres	1,413—1,766
Assembly-rooms and halls for long receptions	2,119
Halls for brief receptions; lecture rooms.	1,059
Primary Schools	42—4,530
Adult Schools	833—1,059

I am unable to say why he placed a higher proportion of air for primary schools than for adult schools. It may be an error of the translator's.

It will be noticed that his quantities of air do not fall so far below what is considered very fair practice of the present day.

MIXING THE AIR—OR MIXING VALVES.

Morin was probably the first to point out the importance of keeping the quantity of air admitted to a building *constant*, while making its temperature *variable;* the variations in temperature being to suit the changes in the outside temperature.

The only general method in vogue previous to about 20 years ago was to close the register when the room was sufficiently warm ; which, of course, not only cut off the heat supply, but the air supply as well, interrupting the fresh air supply and nullifying ventillation.

This, however, is changed now in many buildings that are systematically ventilated.

General Morin called attention to the necessity of the "mixing valve" in the following words :

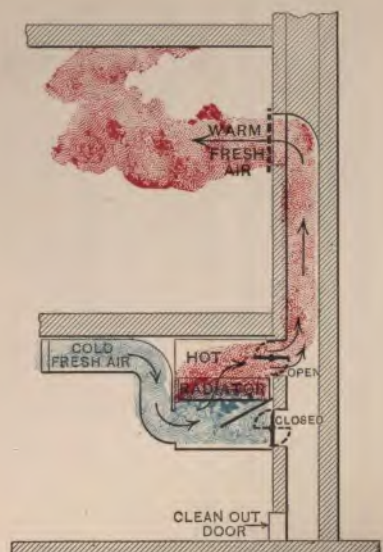

WARM
FRESH
AIR
COLD
FRESH AIR
HOT
RADIATOR
OPEN
CLOSED
CLEAN OUT
DOOR

FIG. 2

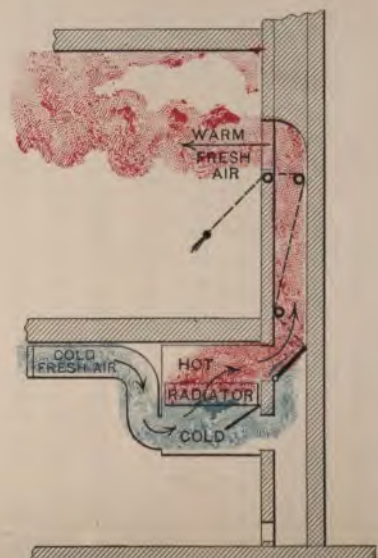

WARM
FRESH
AIR
COLD
FRESH AIR
HOT
RADIATOR
COLD

FIG. 2'

"During the period of artificial heating, it is proper to reserve means of mixing with the warm air, supplied with the heating apparatus, cool air, the amount of which may be regulated by convenient registers. For this purpose the warm air supplied by the heating apparatus should be received in a special register or mixing-chamber, into which the cold air should also enter before passing into the distributing pipes."

The usual method of accomplishing the foregoing, now followed in the United States, is shown in the cut. (Figure 2 and Figure 2').

The dampers "b" "b" are connected with a rod and operated from the room by hand-pulls, or automatically operated by pneumatic pressure controlled by a thermostat.

Various modifications of this method of mixing warm and cold air are in use, and those introduced here are simply to show the principle involved.

WARMING AND VENTILATION OF A SCHOOL.

The usual school room for from 40 to 50 pupils, as now commonly designed, has a floor space

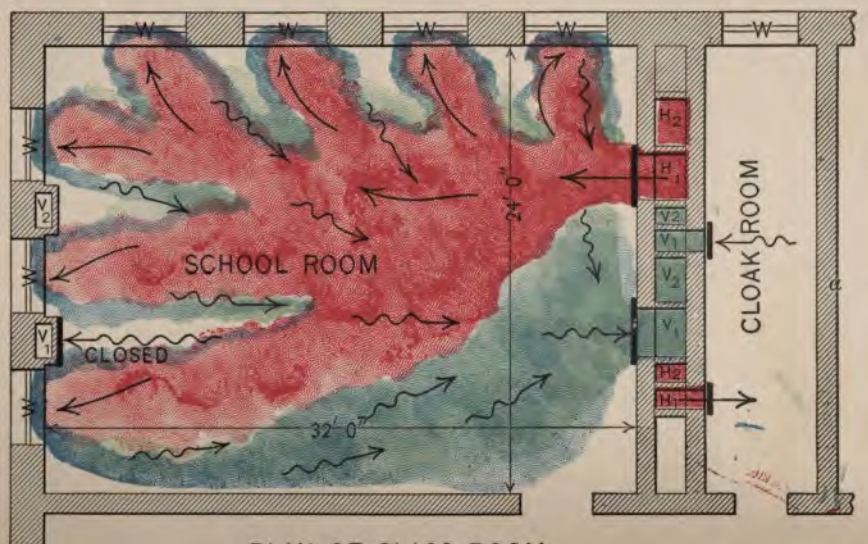
of about 24 feet by 32 feet, with light on at least two sides of the room ; the general endeavor being to have the sitting so arranged that the light will come in over the left shoulder of the pupil. A sketch of such room is shown in Figure 3.

Provision should be made for the admission of at least 100,000 cubic feet of fresh air to one such room in an hour. It may be that it will not all be required, even to comply with what is known as the "Massachusetts' Law," (30 cubic feet per child per [redacted].) MINUTE.

The admission of this air should be above the head-line, and one inlet register is sufficient.

Experiments have demonstrated that the necessary flue for such a room should have a cross section of not less than 3 feet in its smallest part, and that 4 feet is probably the limit required, the latter being the size now adopted by the writer.

It is the custom in New York City schools to reinforce the warm air system by a direct system, the object being to maintain the heat of the room by direct radiation when the fans are not running,



PLAN OF CLASS ROOM
SHOWING DAY CIRCULATION.

FIG. 3.

such as at night, etc., using the fans only during the hours of school.

It has been found that when a quantity of air equal to 100,000 cubic feet is admitted to an ordinary school room in an hour, that this amount of air can be admitted and withdrawn without appreciable draughts, at a temperature sufficiently low to prevent the room from being overheated. Under this condition of ample quantity and low temperature, it has been found, except in exceedingly cold parts of the United States, that direct radiation can be dispensed with and still give comfortable conditions at all parts of the room.

It is not desirable, however, from a point of economy of maintenance, to admit such large quantities of air when the school is not in session; therefore, in the construction of a heating and ventilating apparatus for a school, it is desirable either to provide a reasonable quantity of direct radiation or to design the flues and the indirect portion of the heating apparatus in such a manner that sufficient air will pass through the flues by natural draught to maintain the heat when the school is

not in session, but with a greatly reduced quantity of air and with a very much increased temperature above what is necessary when the school is in session.

A register of 50% greater area than the cross section of the air flue, when placed above the headline, the lower edge being 7 to 8 feet from the floor, will not cause inconvenience as long as the temperature of the entering air is above the air of the room, although the velocity of the air may be 4 or even 5 feet per second.

In the matter of withdrawing air from a school room, the air should be taken from as near the floorline as possible, and preference should be given to a register that will be low and wide rather than the reverse. Building construction, of course, sometimes interferes with the proper shaped flue to secure the best results. The architect, however, should endeavor to make the flues wide, so that the register can be low, and no objection should be made to having the register partly in the baseboard, as appearance should give way to utility in schools.

The lower or "floor vent registers" can be in the same wall or group as the heat registers with the outlet at the floor, and it is probably the best position for them.

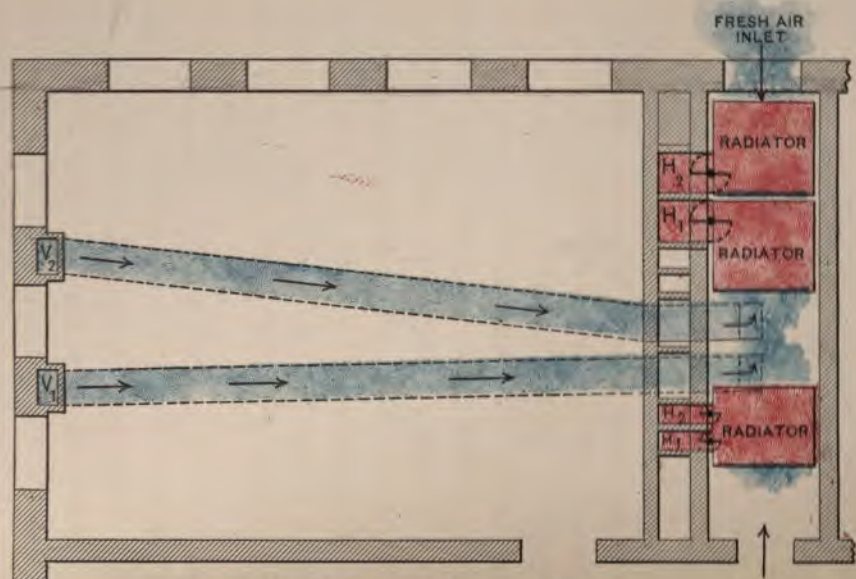
The question of ceiling ventilation and ceiling or upper side wall registers in a school room is a very unsettled one. In winter time, it is probably unnecessary to have them, although this does not always satisfy, and for this reason it is customary to place another ventilating register in the same vent flue as the floor register but near the ceiling. This brings the ceiling outlet too close to the inlet or heat register, resulting in robbing the room of its heat, and the "short-circuiting" of the fresh air current when the upper register is open. For this reason perhaps it would be well to have a double set of vent registers and vent flues to each room when possible; the lower vent registers being placed near the floor in the flue group with the heat flues, and the upper vent registers near the ceiling in another group remote from the heat. This will admit of both floor and ceiling ventilation at the same time. It will also prevent the

intensity or draught of the Floor "vent" from being interfered with when the upper vent is opened, and it will prevent short-circuiting to a very great extent.

All schools designed for forced ventilation should also be arranged so that in case the forcing or fan mechanism gets out of order, that air and heat sufficient will still enter the rooms by natural methods to keep them comfortably warm, so that it will not be necessary to dismiss the school through temporary injury to the fan or motor.

Figure 3 shows the ground plan of a typical school room, arranged for seating from 40 to 50 pupils; and the object of introducing these diagrams here, is to discuss the question of a standard relation between the school room and its warming and ventilation.

The tendency lately is to provide what may be called a "breathing wall." This wall may be on the long or the short side of the room, though presumably it is best to have it on the short side and the wall between the school room and the cloak room is best taken for this purpose. If it can be



BASEMENT PLAN, NIGHT FLUES.

FIG. 4.

arranged by the architect that it is not a construction wall, all the better.

When this wall is used, easy access is obtained for the warm air through the flues to both the school room and its corresponding cloak room, as shown by the arrows; the flues simply opening on opposite sides of the same wall.

When the wall "a" is used as a "breathing" or flue wall, as occasionally happens, it complicates the entire matter by having to carry both heat and vent flues across the cloak room, and for this reason alone it should not be used as a "breathing wall."

An advantage also of using the wall between the cloak room and the school room as the breathing wall is that the space underneath the lower cloak room can be taken as a heating chamber, or if there is any reason why this room cannot be used as a heating chamber, the heating chamber can be constructed on the opposite side of the wall by taking a portion of the basement room usually used as a play room or for toilet rooms.

Reference to Figure 4 will show the arrangement of the radiators or heaters required for a two-story

school building. There is sufficient room, however, in the ordinary breathing wall to carry ample flues for three stories, but that is about the limit for the size flues required for ordinary school rooms.

For a two-story school, it is necessary to find room for four large flues, aggregating not less than 3 square feet each, and for four small flues (two heats and two vents) the large flues for the school rooms and the small flues for the cloak rooms.

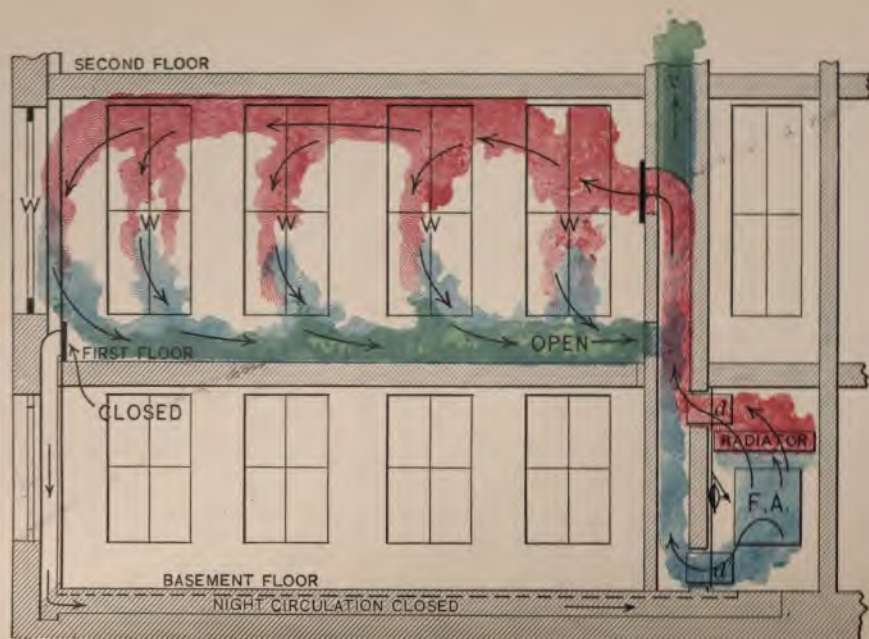
Another story will about take up the remaining blank space in the flue walls, requiring, of course, a rearrangement of the flues as shown here.

Flue H_1 (Figure 3) shows the heat flue for the first story, and alongside of it is flue H_2 which sends warm air to the second story. Their relation to the radiators is shown in Figure 4.

The small flues H_2 and H_1 show the flues in their relation to the cloak rooms.

The flues V, in like manner (Figure 3) show the main ventilating flues, V_1 being the first story flue, and V_2 the second flue.

I will say that the second story vent does not run down, as shown in Figure 3, but the space in



SECTION THROUGH HOT AIR FLUE
SHOWING DAY CIRCULATION

FIG. 5.

the wall is required for it, and sometimes the under part of it is used as a heating flue so as to save wall space.

Figure 5 is a simple section through the basement and first floor of the same school building, showing the relation of the heating chamber to the hot air flue, with the radiator, cold air duct, and the position of the hot air or inlet register (the lower edge of which is now always placed above the head-line.) To determine the height of the register, one wants to be guided by two conditions : (1) that the register must be sufficiently far above the head-line so the air will not inconvenience one, and (2) to be sufficiently far from the ceiling to prevent a dark streak which soon appears thereon (caused by the invisible dust carried in with the fresh air), when the register is very close to the ceiling.

Figure 5 is a vertical section through the hot air duct, the fresh air inlet "F. A.," showing how the air passes to the radiator to be warmed, and through the upper part of the switch valve, thence through the flue to the register.

When the room is sufficiently warm, the switch valves "d" and "d'" change their position so that "d" is closed and "d'" is open, when the passage of air will be through the lower valve, thus permitting cold air to pass into the room.

By fixing these valves "d" and "d'" at any intermediate position, mixed air will pass up the flue, usually at a little above 70 degrees, keeping the room at the constant and desired temperature. When these contrivances (switch valves) are automatically operated by a proper system of thermostatic control, the variations of a class room can be kept within 2 degrees Fahrenheit.

Figures 2 and 2' show modifications of the switch valve; Figure 2 showing a good arrangement of valve as automatically controlled, while Figure 2' shows the hand-controlled switch valve. It is nothing but a piece of sheet iron fastened in the flue at the point shown and arranged to be drawn against the upper opening by a hand-pull within the school room. The valve divides the flue so that cold air from below can pass up and mingle with the warm air from above the radiator, and

SECTION THROUGH VENT FLUE

thus pass into the room. The objection to the hand-controlled mechanism, however, is that the teacher and those concerned will never think of adjusting it until the room becomes, I will say, a little too warm, and that again they will not think of changing it until the room becomes a little too cold, so that it is alternately a little too hot and a little too cold, to the annoyance and discomfort of all concerned. The theory is right, but the practice is wrong, and the only relief from the annoyance of it, is automatic control, which practically anticipates the requirements of the room.

Figure 2 shows the clean-out at the bottom of the flue, which is very necessary.

Figure 6 is a vertical section through the same wall as Figure 5. This section, however, is through the vent flue V_I (Figure 3) while Figure 5 is a vertical section through the heat flue H_I (Figure 3.)

Figure 6, therefore, is a vertical section through the main vent flue of the school room, and the heat and vent flues are shown in separate illustrations rather than in the conventional manner so as to overcome confusion of ideas, if possible; Fig. 5, being the section through the heat flue.

I might say that the pink, of course, in the illustration, indicates heat, and that the green indicates foul or vitiated air, while the blue indicates fresh air, or air that is relatively cold, such as at the windows. Red also represents the primary source of heat, or the radiators.

The ordinary course, therefore, of the fresh air, is from the inlet through the radiator and through the flue to the room, thence making a circuit to the windows and becoming lightly cooled, (indicated by blue,) thence passing to the floor and becoming vitiated and passing out at the flues marked in green, Figure 6.

The warm air as it leaves the register will rise to the ceiling and expand and flow out under the same; the windows of the building supplying the power to keep up the circulation within the room, and they perform a very important function in the mixing of the air. The glass of each window being cooler than the temperature of the internal air, made so by the temperature of the external air, causes the downward movement of the air to the floor, across which it flows to the point of outlet. Every child within the room also becomes a factor for air moving. His or her body is warmer than the air so that there is an upward current of air at each child, and this upward current carries the

exhalations with it to the ceiling, there to mix with the warm fresh air, flow across the ceiling to the various windows, down at each window, and across the floor towards the outlet. It may be said that the child is breathing the floor air, which is passed to the ceiling over its body, and this to a great extent is true; but the question must here be asked, "is this floor air foul?" and it may be answered in the negative, so long as it is known that a reasonable per capita of fresh air has been admitted.

It is utterly impracticable to bring fresh air directly to the lungs of each child or person in a crowded or partially crowded room, and all that is practicable is to admit sufficient fresh air per person to secure a dilution or standard of purity which is reasonably good, and which in fact, can be made very good if sufficient fresh air is admitted.

The conditions in any school room are analogous to admitting a tiny stream of ink to a reservoir of water, while at the same time you admit a very large quantity of pure water to the same tank, allowing an equal quantity to overflow. If there are any fish in this tank, it is possible, by admit-

ting sufficient pure water, to keep them in good health, and they will not be poisoned by the small stream of ink, provided the water in the tank is kept well agitated; and in the case of the school the cold of the windows and the heat of the bodies of the children are the agitators. These two forces produce an agitation which keeps the mixture at a nearly constant and equal condition of freshness (or foulness), at every part of the room.

There seems to be an idea that it is preferable to have the heat flue as near the outside wall and windows as possible, and that the vent flue should be as near the inside or warm corner of the room as possible. I am not convinced that much is gained in choice of positions. When the heat flue is near the outside wall, the air is projected along the wall and made to turn at the short side of the room, and in that way to help the circulation. It may be claimed there is an inert patch at the ceiling in the warm corner of the room if this is carried out. If such is the fact, then it would be better to have the inlet or hot air flue in the warm corner

of the room, as it would be the means of stirring up this inert patch.

These ideas are put forth because we are apt to find persons arguing from both sides of this question, and my own opinion is that there is very little gained or lost, no matter what relative positions the inlets and the outlets have, provided the outlet or vent is pretty near what may be called the warm corner of the room.

When 100,000 cubic feet of air are admitted through the hot air flue H_1 in an hour, and drawn out through the vent flue V_1 in the same time, it is very reasonable to assume that the conditions within that school room are good, and when this quantity of air is passed through a school room, not only will the air be kept at a fair standard of purity, but an equality in temperature will be maintained so nearly alike between the ceiling and the floor that they will not vary 4 degrees, and this in the outer corner of the room at "X," in what may be called the focus of two windows.

When large quantities of air at low temperatures

are admitted to a room, a wonderful uniformity of temperature is the result.

When small quantities of air are admitted, at high temperatures, great unevenness of temperature prevails.

When large quantities of air are admitted to a room, such as will be required in a school room, if one puts his hand over the inlet register, the temperature of the air will feel cool to the touch. This is because the air is coming in considerably below the blood temperature, but still sufficiently high to maintain the temperatnre of the room. If it came in at a higher temperature, it would simply overheat the room, and either the temperature or the quantity of air admitted would have to be lessened.

Supplementary direct radiation is sometimes used in school rooms, usually in the form of a coil of 2 or 3 pipes placed on the outside walls under the windows.

There are two reasons for these coils. They may be necessary in very cold or exposed places so as to prevent too great a down draft at the win-

dows, but this interferes with air mixing and diffusion, as it reverses the window current. The other reason is on account of the extreme expense of maintaining the heat of a school building at all times by indirect radiation. In other words, an attempt is made to use the indirect radiation and ventilation during the school session, and to keep the building warm or partially warm at night by the direct coils. This, however, is hardly ever carried out, and the alternate use of coils at night or in the early morning and afternoon, and ventilation during the school hours becomes a dead letter, as it will not be properly attended to, so that there is nothing but a confusion of the heating system and general annoyance.

For this reason it is better, when possible, to omit the direct radiation from a school room. If it is used, it should never be used except in connection with an automatic shut off system.

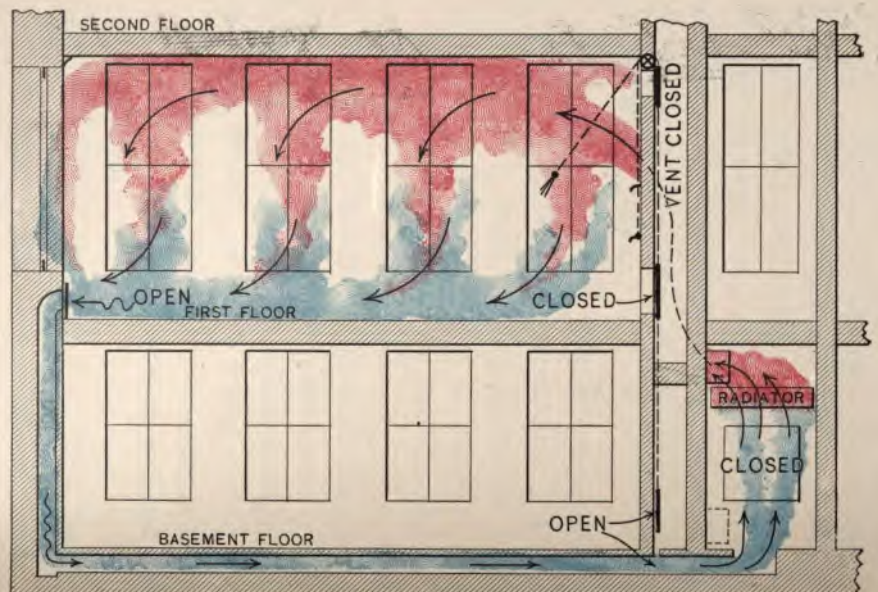
It is necessary, however, to practice economy in the warming of schools, for should the ventilating system be run during the 24 hours, or even during 16 hours of each day, the cost of warming the

school is either doubled or trebled, as the case may be. This is a great cause for complaint with schools :—the fuel bill is simply enormous, as the full million or two million or three million cubic feet of air (according to the size of the school) that is admitted each hour, has to be warmed from the outside to the inside temperature, and then allowed to escape at the latter temperature, tending to warm all out-of-doors.

This can be avoided, however, to a very great extent, by providing an internal or night circulation. This is rarely carried out in its entirety, though a modification of it is sometimes used, whereby the cold air inlets and the ventilating outlets are all closed ; the class room doors opened, so that the air from the class rooms is allowed to pass down through the halls and stairways to the basement, and enter the chambers through a doorway from the hall, as at "b." Fig. 4.

This, however, has its disadvantages as some rooms will warm and some rooms will not, due to local conditions.

To insure inside or night circulation, therefore,



SECTION SHOWING NIGHT CIRCULATION

FIG. 7.

in its best form, there should be a night circulating flue arranged from each room. This is shown by dotted lines in Fig. 5 and by blue on Fig. 7 which latter is a section through this flue. It is best arranged so as to start on a cold side of the room, as shown in Figure 3 at "c." It drops to the basement, as shown in Figure 7, and passes under the basement floor, returning to the heating chamber as shown by the flue lines and arrows. At this time, the fresh air inlet (F. A.) is closed and the regular vent flues shown in Fig. 6 are closed so as to prevent the escape of heat or air in that direction. It will be noticed by Figure 7 that one operation from each school room can be made to accomplish this result, by the use of a pull.

In the vent flue there are three dampers, arranged on a single pull. The dampers are shown in what might be called the "night position." In other words, the regular ventilating flues are shut off and the night or internal circulation flue is opened. The janitor, or some one appointed for that purpose, should enter the room at a few minutes before 9 o'clock in the morning, unhook the pull from the wall and drop the dampers until they assume

the position shown in Figure 6, when full ventilation is obtained for the day session.

I consider the drawings here shown to be a fairly full exposition of the most recent principles involved in school room ventilation. They are the result of experience, and all those who have made a study of the question are gradually being forced to the same conclusions.

CARD BY THE AUTHOR.

THE author offers his services as an Expert and Designer of heating, cooling and ventilating plants, power houses and general engineering.

He has had thirty years experience, both practical and theoretical, with a thorough knowledge of all the minutia of detail of construction. His experience enables him to assure economy, both in design and maintenance.

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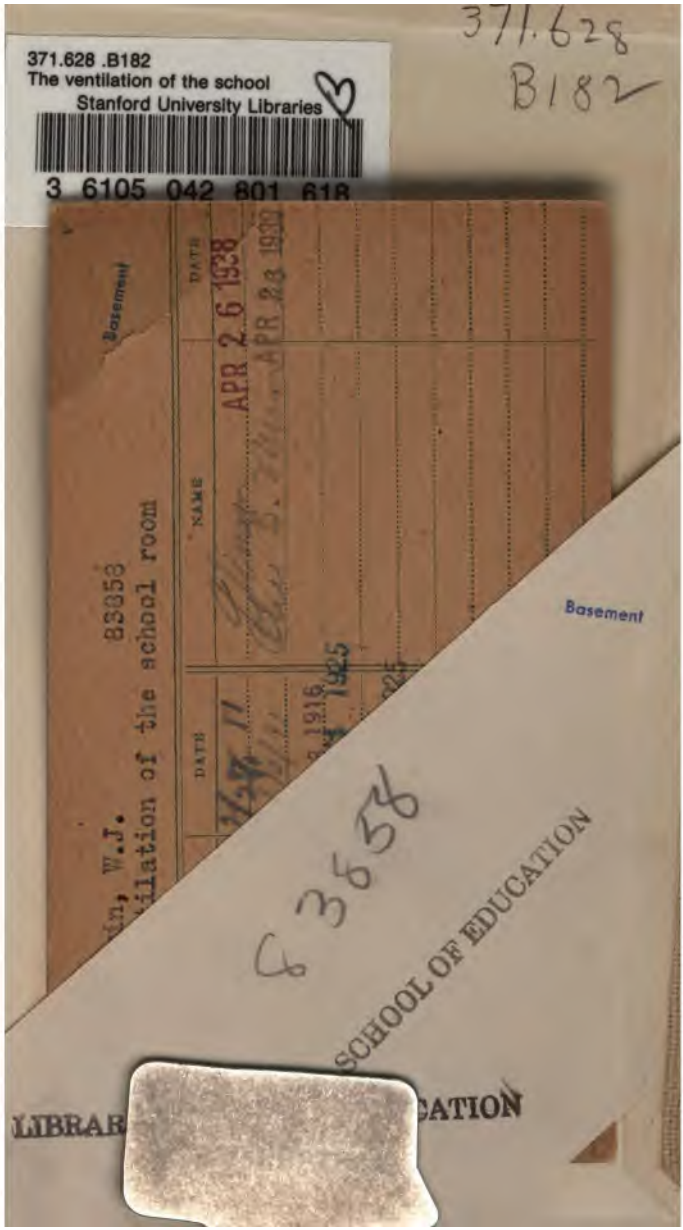

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